INFLUENCE OF DUCTILITY ON THE RESPONSE OF SIMPLE STRUCTURES TO EARTHQUAKE MOTIONS

BY

SAI-LUNG PAN

B.S., Hangchow Christian College, 1945
M.S., University of Illinois, 1949

AN ABSTRACT OF A THESIS

SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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INFLUENCE OF DUCTILITY ON THE RESPONSE OF SIMPLE STRUCTURES TO EARTHQUAKE MOTIONS

The present investigation is an attempt to assess the influence and importance of the ductile property of steel structures in connection with their ability to resist earthquake damage.

Since the intensity and detailed characteristics of future earthquakes are unknown and since the precise physical properties of structures are not readily determinable in advance of construction, the point of view is taken that it is not feasible to base aseismic design on dynamical analyses sensitive to details of the earthquake accelogram. On the basis of studies of past strong-motion earthquakes, Housner has suggested that, *so far as their effect on structure is concerned,* actual earthquakes may be replaced by fictitious ground motions. Following this suggestion a number of possible earthquake motions have been constructed. The response of a class of simple structures to each of five of these motions has been determined.

The type of structure investigated has been the steel skeleton single-story mill building. It is assumed that the mass of the structure is concentrated at the tops of the columns and that this mass is symmetrical with respect to the rigidity distribution of the structure. This condition implies that the building will not tend to twist about a vertical axis when subjected to ground accelerations. In order to simplify the analysis sufficiently to permit inclusion of the ductile behavior of the structures, the roof trusses are assumed to be infinitely rigid as compared to the columns. The equivalent spring constants are evaluated by neglecting the horizontal resistance of walls and assuming that columns are rigidly jointed at the top. With these assumptions it is apparent that these structures will exhibit a "shear" type of deformation. Initial stresses are entirely neglected in the analysis.

With the assumptions mentioned in the above paragraph, this class of structure may be treated as a single-degree-of-freedom system. Within limits determined by the instantaneous value of the permanent set, the motion of the structure is taken to be elastic, outside these limits it is taken to be perfectly plastic.

A graphical method of analysis is developed for determining the response of an elastic-plastic single-degree-of-freedom system to a complex base motion. The method, based on the phase-plane approach, can readily be extended to include the effect of strain-hardening. Perfect plasticity has been introduced only as a convenience.

The conclusions of the investigation can be summarized as follows:

(A) When computed on the assumption of perfect elasticity, the responses of two similar structures to the same ground motion may be entirely different if their natural frequencies are slightly different. The effect of ductile action is to lessen this variation in response.

(B) As Δ, the maximum deflection which the structure can undergo before the onset of plastic action, is reduced, the influence of ductility increases and the structure shows a much smaller response to random ground motion. This effect appears to be quite pronounced and indicates that analyses based on completely elastic behavior are apt to give misleading results.

(C) Since, other things being equal, stiff structures will have smaller values of the ductility index, Δ, it follows that such structures will undergo less deformation, provided that the deformation does not reach such an extreme magnitude that actual rupture of the steel skeleton takes place.

Stiff structures which survive an earthquake may therefore be expected to suffer less superficial damage.

(D) Within the range of normal design, the maximum shearing force encountered during the earthquake generally

increases as the stiffness of the structure is increased. Since the resistance to shear also increases with stiffness, this cannot be used as an argument against stiff design.

(E) The average of the maximum response for the five different ground motions studied becomes more and more nearly independent of the natural frequency of the structure as the influence of ductility is increased.

It should be carefully borne in mind that these conclusions are limited to single-story mill buildings having steel skeletons. They are also limited in validity by the fact that they are based on the results of studies of only five ground motions.

VITA

Sai-lung Pan was born on September 12, 1921, in Shanghai, China. After graduation from the University of Shanghai, Middle School, in 1941 he entered Hangchow Christian College and received the degree of Bachelor of Science in Civil Engineering in June, 1945. He worked for the Public Works Department of Shanghai in 1946. In 1947, he was construction inspector for the erection of a hospital in Yuyao, China. He entered the Graduate College of the University of Illinois in February, 1948, and received the degree of Master of Science in Civil Engineering in February, 1949. He held a Fellowship in the Civil Engineering Department of the University of Illinois from February, 1949 to June, 1950, and a Research Assistantship during the fall semester, 1950.

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